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Letterman et al.

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(54) **AIR DISTRIBUTION SYSTEMS AND METHODS**

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(51) **Int. Cl.**

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G05D 23/19	(2006.01)
F24F 11/46	(2018.01)
F24F 11/74	(2018.01)
F24F 11/80	(2018.01)
F24F 120/14	(2018.01)
F24F 110/10	(2018.01)
F24F 120/12	(2018.01)
F24F 11/58	(2018.01)

(52) **U.S. Cl.**

CPC ***G05D 23/27*** (2013.01); ***F24F 11/46*** (2018.01); ***F24F 11/74*** (2018.01); ***F24F 11/80*** (2018.01); ***G05D 23/1917*** (2013.01); ***G05D 23/1927*** (2013.01); ***G05D 23/1932*** (2013.01); *F24F 11/58* (2018.01); *F24F 2110/10* (2018.01); *F24F 2120/12* (2018.01); *F24F 2120/14* (2018.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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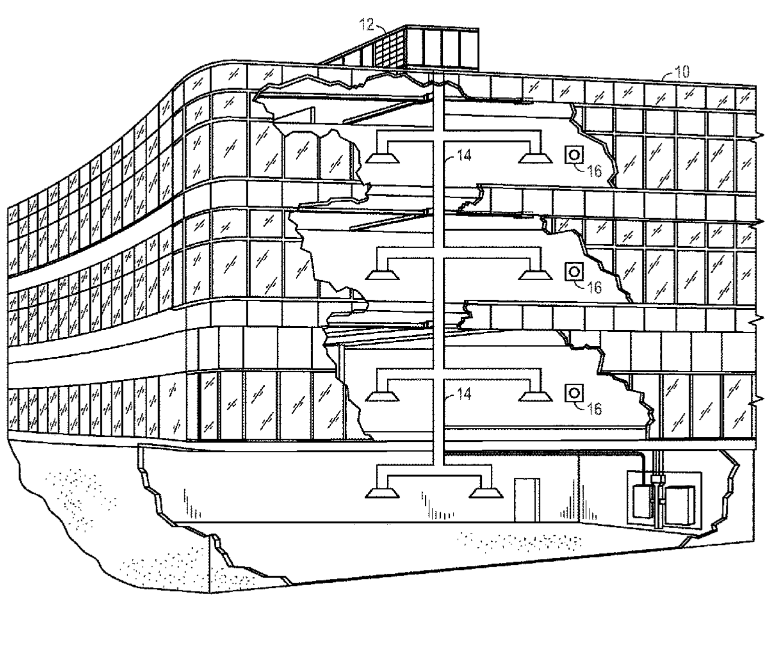
(57) **ABSTRACT**

The present disclosure relates to a heating, ventilation, and air conditioning (HVAC) system including a sensor system configured to detect heat indications within a plurality of areas of a conditioned space, wherein the sensor system comprise a thermal light detector, and a controller configured to receive feedback from the sensor system and, based on the feedback, control airflow distribution, via an airflow distribution system, such that airflow management for each of the plurality of areas is individually correlated to a heat indication detected for the respective area.

22 Claims, 7 Drawing Sheets



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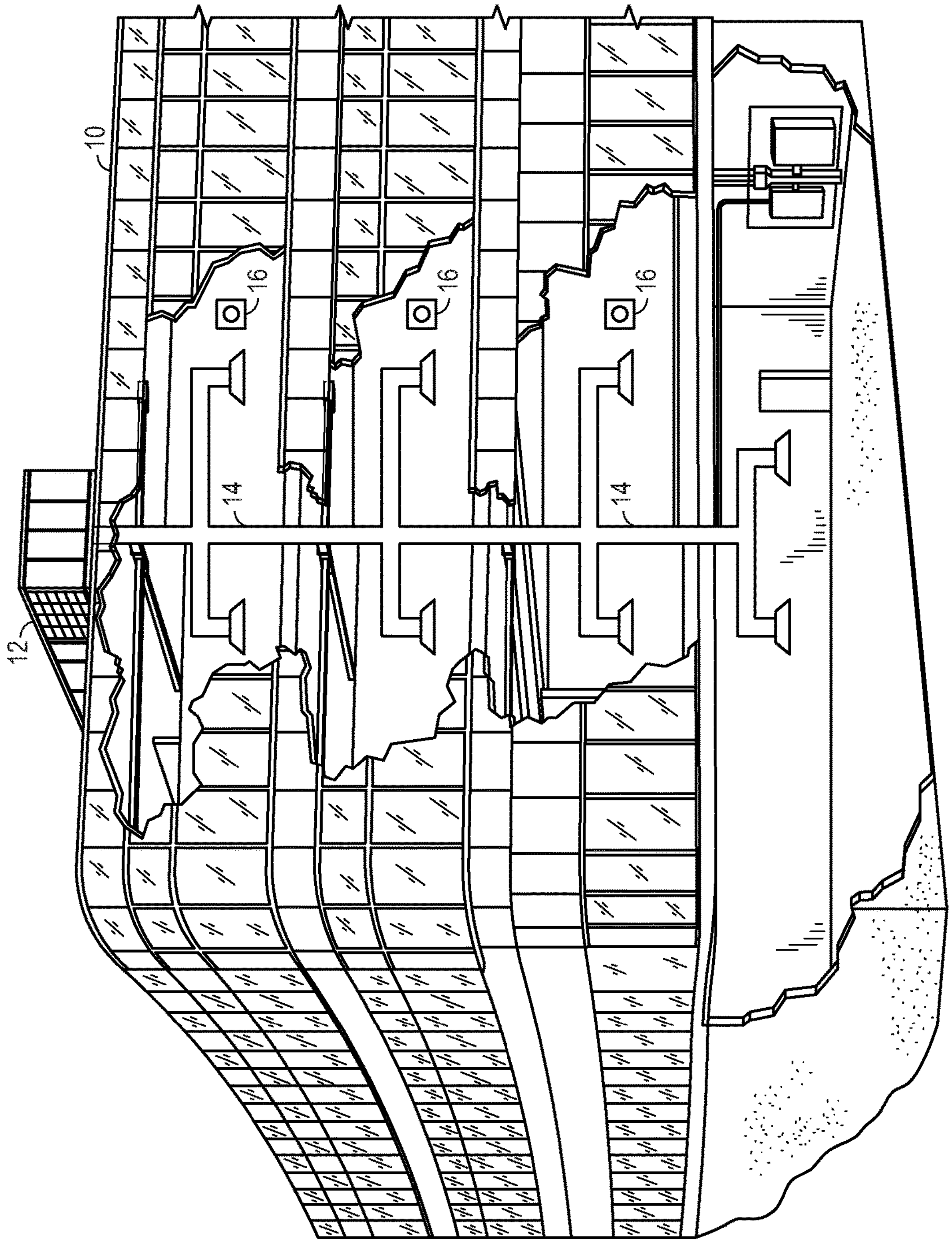

FIG. 1

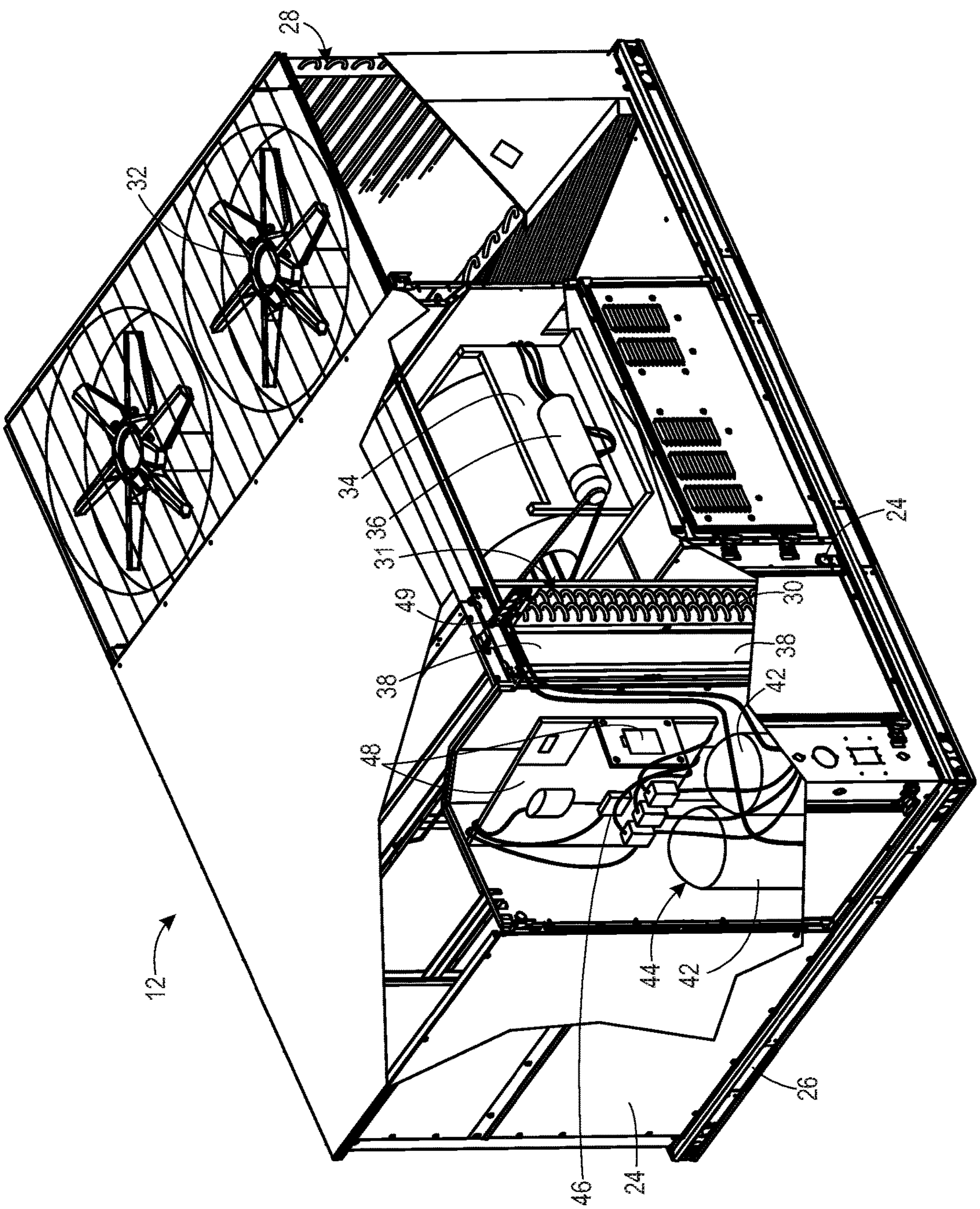

FIG. 2

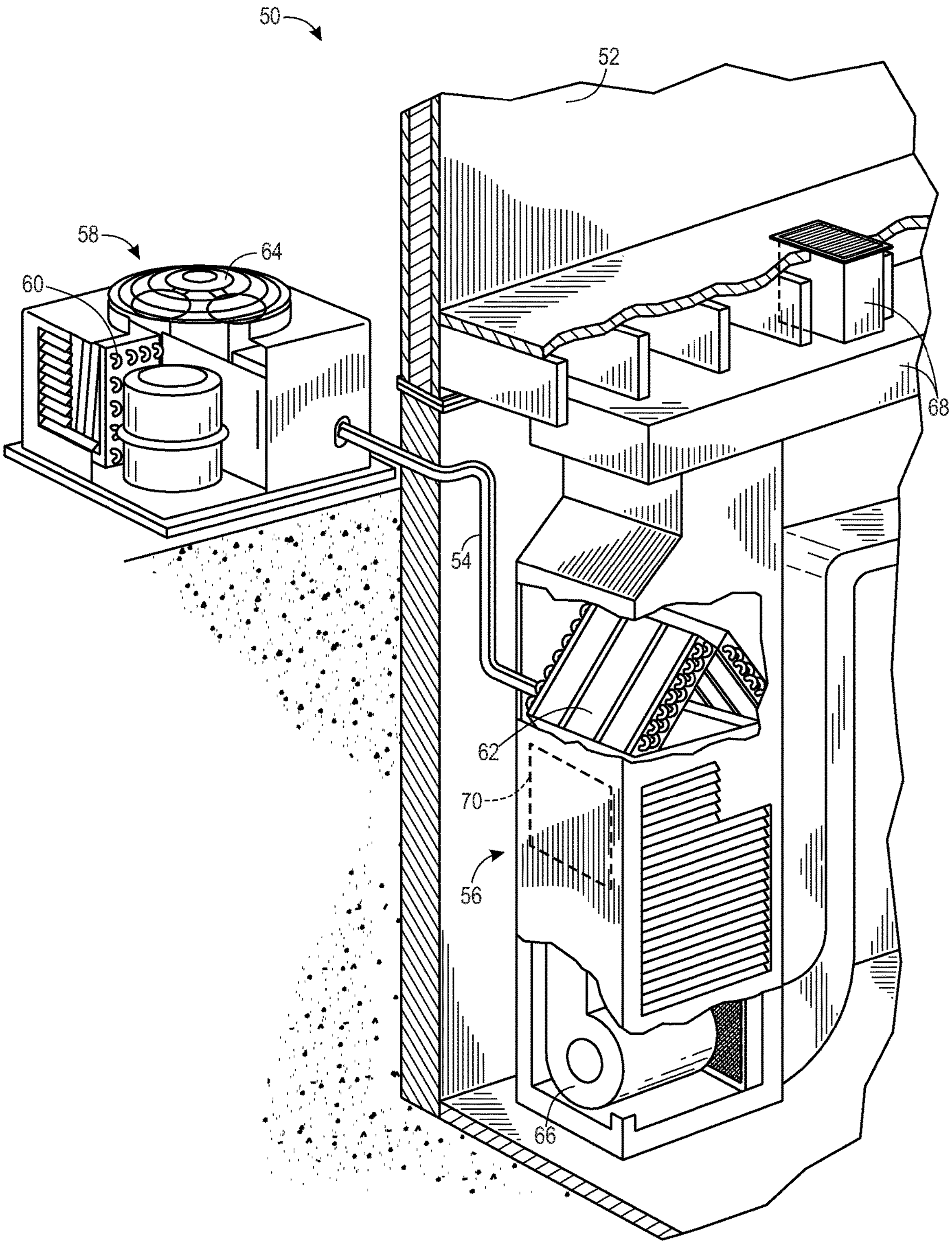

FIG. 3

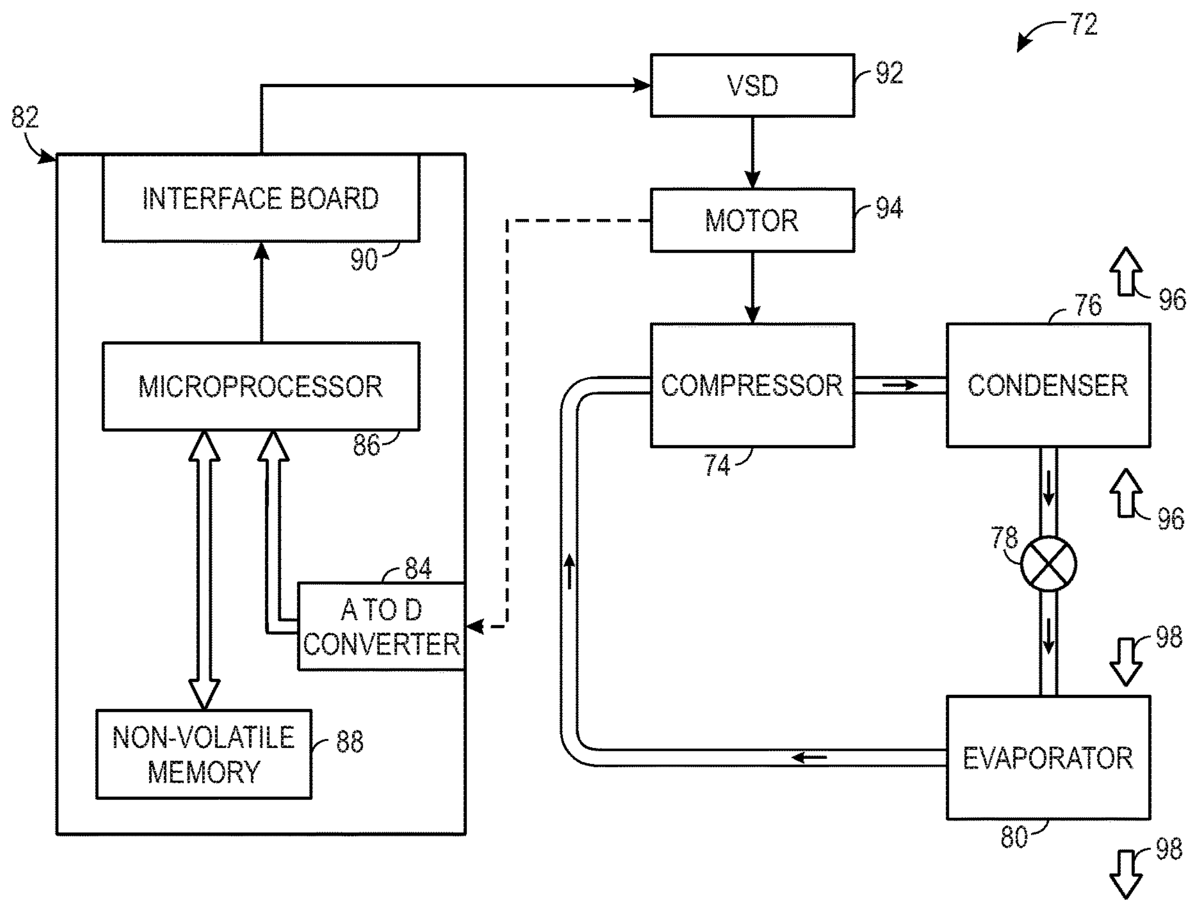
72
82
INTERFACE BOARD
90
MICROPROCESSOR
86
84
A TO D CONVERTER
NON-VOLATILE MEMORY
88
VSD
92
MOTOR
94
COMPRESSOR
74
CONDENSER
76
96
96
78
98
EVAPORATOR
80
98

FIG. 4

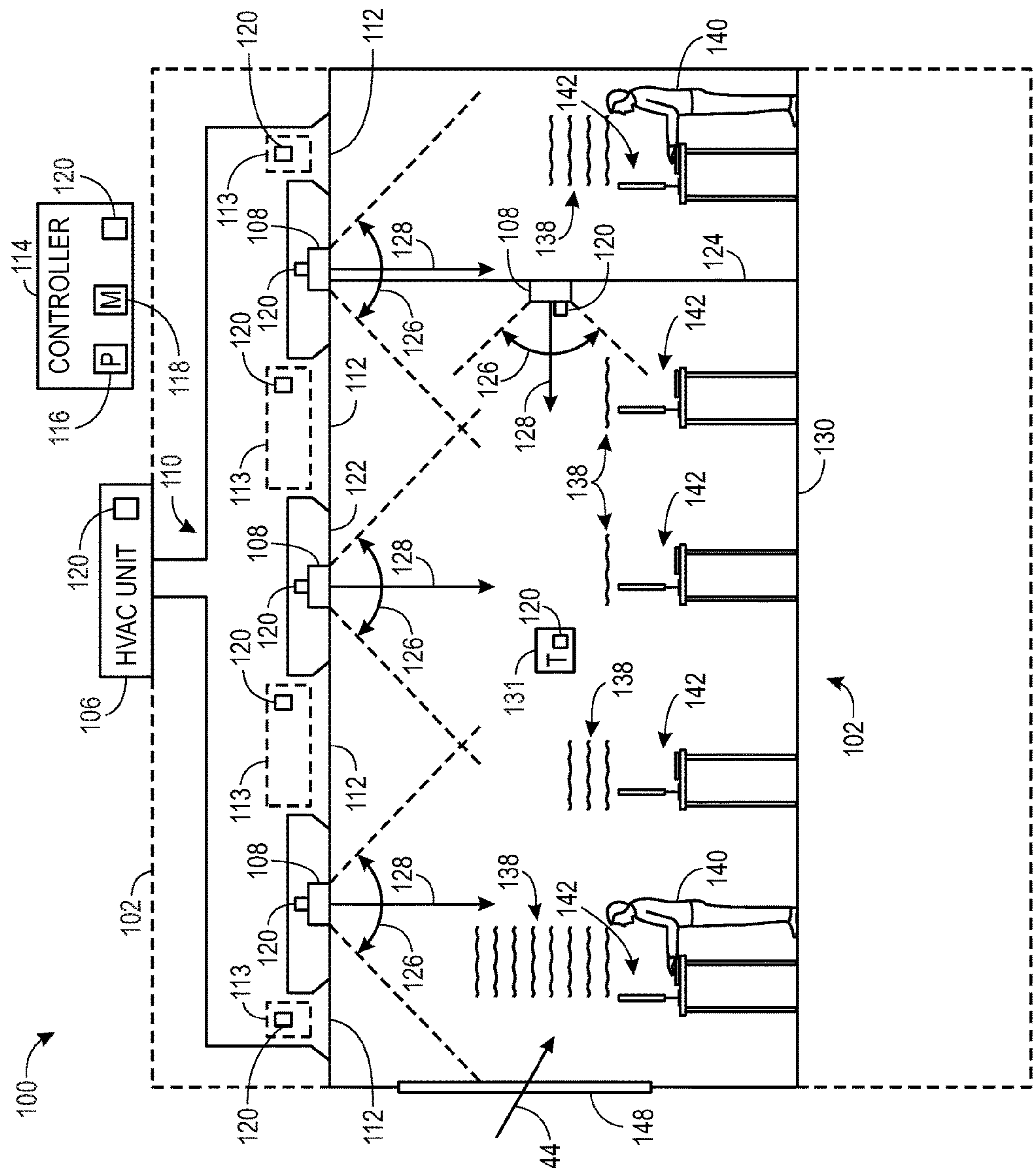
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FIG. 5

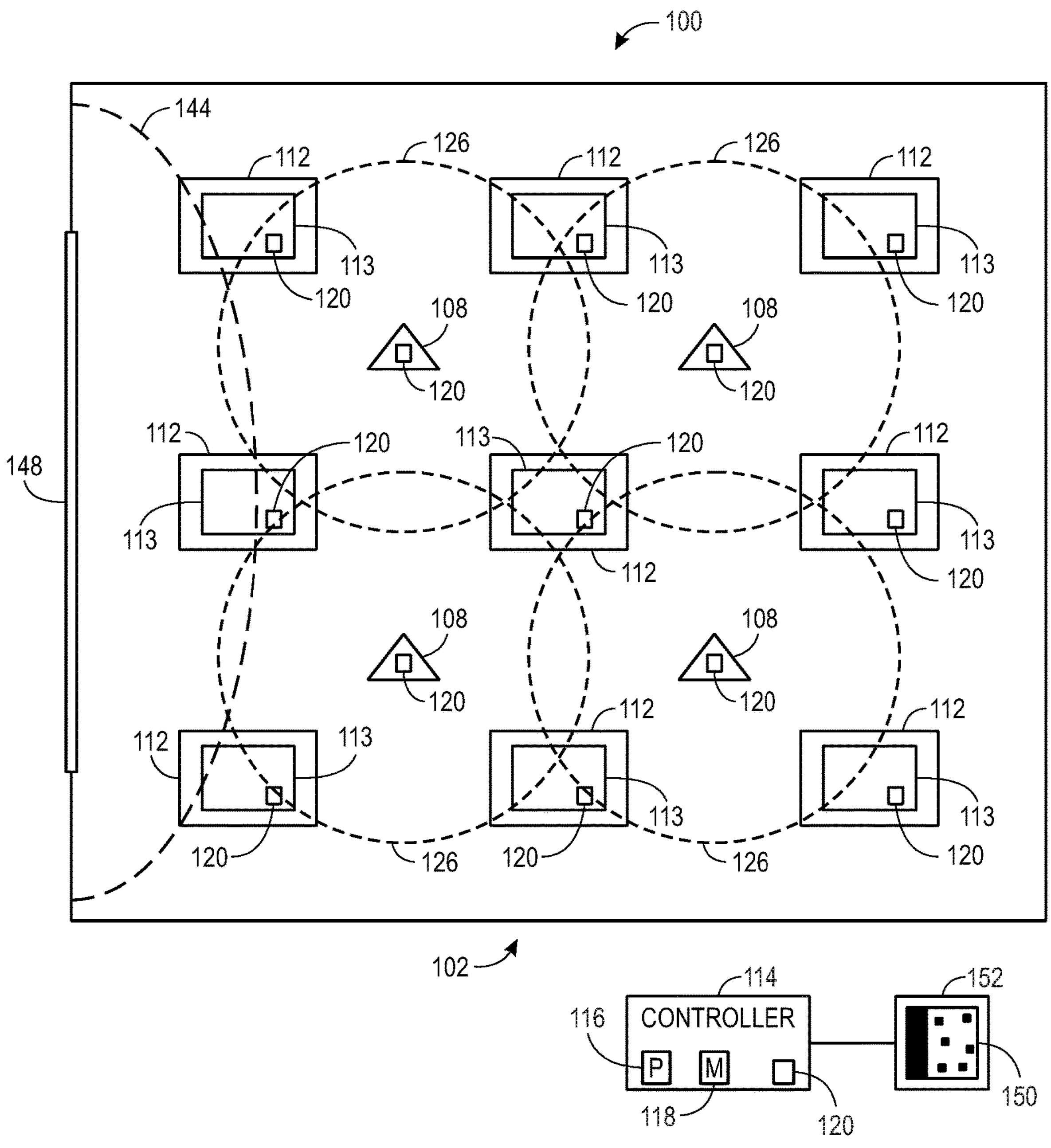
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FIG. 6

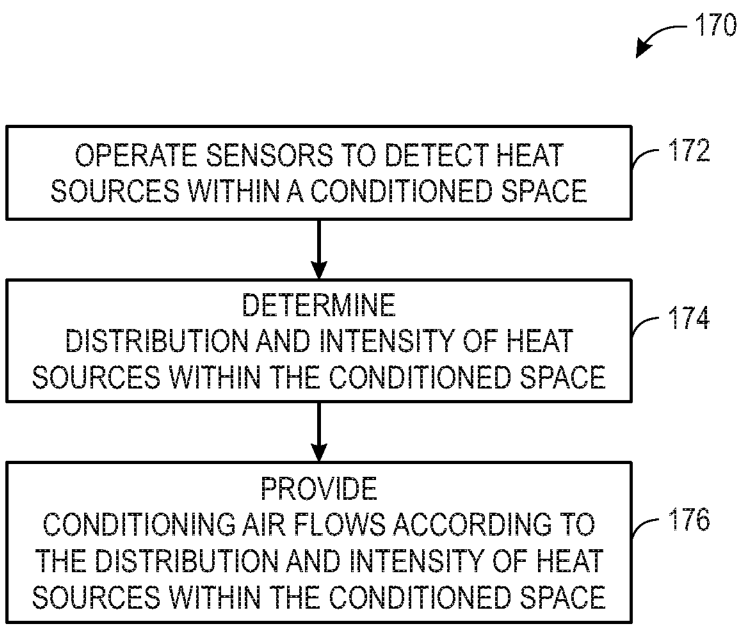
170
OPERATE SENSORS TO DETECT HEAT SOURCES WITHIN A CONDITIONED SPACE
172
DETERMINE DISTRIBUTION AND INTENSITY OF HEAT SOURCES WITHIN THE CONDITIONED SPACE
174
PROVIDE CONDITIONING AIR FLOWS ACCORDING TO THE DISTRIBUTION AND INTENSITY OF HEAT SOURCES WITHIN THE CONDITIONED SPACE
176

FIG. 7

AIR DISTRIBUTION SYSTEMS AND METHODS

CROSS REFERENCE TO RELATED APPLICATION

This application is a Non-Provisional application claiming priority to U.S. Provisional Application No. 62/505,600, entitled "ADAPTIVE DISTRIBUTION WITH INFRARED SENSORS," filed May 12, 2017, which is hereby incorporated by reference in its entirety for all purposes.

BACKGROUND

The present disclosure relates generally to heating, ventilation, and air conditioning systems. A wide range of applications exist for heating, ventilation, and air conditioning (HVAC) systems. For example, residential, light commercial, commercial, and industrial systems are used to control temperatures and air quality in residences and buildings. Such systems often are dedicated to either heating or cooling, although systems are common that perform both of these functions. Very generally, these systems operate by implementing a thermal cycle in which fluids are heated and cooled to provide the desired temperature in a controlled space, typically the inside of a residence or building. Similar systems are used for vehicle heating and cooling, and as well as for general refrigeration. In many HVAC systems, heated or cooled air may be administered based on readings from a thermostat.

SUMMARY

The present disclosure relates to a heating, ventilation, and air conditioning (HVAC) system including a sensor system configured to detect heat indications within a plurality of areas of a conditioned space, wherein the sensor system comprise a thermal light detector, and a controller configured to receive feedback from the sensor system and, based on the feedback, control airflow distribution, via an airflow distribution system, such that airflow management for each of the plurality of areas is individually correlated to a heat indication detected for the respective area.

The present disclosure also relates to a heating, ventilation, and air conditioning (HVAC) control system including a sensor system configured to detect a distribution of heat within a conditioned space, a plurality of airflow control devices configured to be actuated to control respective airflows from a common source to the conditioned space, and a controller configured to control each airflow control device of the plurality of airflow control devices based on the distribution of heat within the conditioned space.

The present disclosure further relates to a heating, ventilation, and air conditioning (HVAC) system including an infrared (IR) sensor configured to detect heat sources within a room and a plurality of air outlets configured to deliver conditioned air to the room, wherein the HVAC system is configured to deliver the conditioned air through each air outlet of the plurality of air outlets according to a distribution of the heat sources within the room.

DRAWINGS

FIG. **1** is a perspective view of a heating, ventilation, and air conditioning (HVAC) system for building environmental management that may employ one or more HVAC units, in accordance with an embodiment of the present disclosure;

FIG. **2** is a perspective view of an HVAC unit of the HVAC system of FIG. **1**, in accordance with an embodiment of the present disclosure;

FIG. **3** is a perspective view of a residential split heating and cooling system, in accordance with an embodiment of the present disclosure;

FIG. **4** is a schematic view of a vapor compression system that may be used in an HVAC system, in accordance with an embodiment of the present disclosure;

FIG. **5** is a schematic view of an air distribution system, in accordance with an embodiment of the present disclosure;

FIG. **6** is a schematic view of the air distribution system of FIG. **5**, in accordance with an embodiment of the present disclosure; and

FIG. **7** is a flow chart of a process of the air distribution system of FIG. **5**, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

The present disclosure is directed to heating, ventilation, and air conditioning (HVAC) systems which may administer air based on a distribution of heat or heat sources throughout a room, a building, or other conditioned space. Particularly, the HVAC system may include heat sensors or thermal light detectors, such as infrared (IR) sensors, configured to detect heat sources within the room, building, or other conditioned space. The HVAC system may utilize data gathered by the heat sensors to provide conditioning air flows, such as heated or cooled air, to preemptively condition portions of the room, building, or conditioned space as the distribution of heat changes within the portions of the room, building, or conditioned space. For example, as the heat sensors or thermal light detectors detect heat sources in a particular portion of the room, building, or conditioned space, the HVAC system may supply conditioned air the particular portion to preemptively cool the air. Overall, the HVAC system may provide individualized conditioning air flows to respective portions of a room, building, or conditioned space as the heat sensors or thermal light detectors detect changes in heat sources of the area. In this manner, the HVAC system may be utilized more effectively and may reduce stratified zones within the room, building, or conditioned space, such as an uneven distribution of temperatures within the room.

Turning now to the drawings, FIG. **1** illustrates a heating, ventilation, and air conditioning (HVAC) system for building environmental management that may employ one or more HVAC units. In the illustrated embodiment, a building **10** is air conditioned by a system that includes an HVAC unit **12**. The building **10** may be a commercial structure or a residential structure. As shown, the HVAC unit **12** is disposed on the roof of the building **10**; however, the HVAC unit **12** may be located in other equipment rooms or areas adjacent the building **10**. The HVAC unit **12** may be a single package unit containing other equipment, such as a blower, integrated air handler, and/or auxiliary heating unit. In other embodiments, the HVAC unit **12** may be part of a split HVAC system, such as the system shown in FIG. **3**, which includes an outdoor HVAC unit **58** and an indoor HVAC unit **56**.

The HVAC unit **12** is an air cooled device that implements a refrigeration cycle to provide conditioned air to the building **10**. Specifically, the HVAC unit **12** may include one or more heat exchangers across which an air flow is passed to condition the air flow before the air flow is supplied to the building. In the illustrated embodiment, the HVAC unit **12** is a rooftop unit (RTU) that conditions a supply air stream, such as environmental air and/or a return air flow from the building **10**. After the HVAC unit **12** conditions the air, the air is supplied to the building **10** via ductwork **14** extending throughout the building **10** from the HVAC unit **12**. For example, the ductwork **14** may extend to various individual floors or other sections of the building **10**. In certain embodiments, the HVAC unit **12** may be a heat pump that provides both heating and cooling to the building with one refrigeration circuit configured to operate in different modes. In other embodiments, the HVAC unit **12** may include one or more refrigeration circuits for cooling an air stream and a furnace for heating the air stream.

A control device **16**, one type of which may be a thermostat, may be used to designate the temperature of the conditioned air. The control device **16** also may be used to control the flow of air through the ductwork **14**. For example, the control device **16** may be used to regulate operation of one or more components of the HVAC unit **12** or other components, such as dampers and fans, within the building **10** that may control flow of air through and/or from the ductwork **14**. In some embodiments, other devices may be included in the system, such as pressure and/or temperature transducers or switches that sense the temperatures and pressures of the supply air, return air, and so forth. Moreover, the control device **16** may include computer systems that are integrated with or separate from other building control or monitoring systems, and even systems that are remote from the building **10**.

FIG. **2** is a perspective view of an embodiment of the HVAC unit **12**. In the illustrated embodiment, the HVAC unit **12** is a single package unit that may include one or more independent refrigeration circuits and components that are tested, charged, wired, piped, and ready for installation. The HVAC unit **12** may provide a variety of heating and/or cooling functions, such as cooling only, heating only, cooling with electric heat, cooling with dehumidification, cooling with gas heat, or cooling with a heat pump. As described above, the HVAC unit **12** may directly cool and/or heat an air stream provided to the building **10** to condition a space in the building **10**.

As shown in the illustrated embodiment of FIG. **2**, a cabinet **24** encloses the HVAC unit **12** and provides structural support and protection to the internal components from environmental and other contaminants. In some embodiments, the cabinet **24** may be constructed of galvanized steel and insulated with aluminum foil faced insulation. Rails **26** may be joined to the bottom perimeter of the cabinet **24** and provide a foundation for the HVAC unit **12**. In certain embodiments, the rails **26** may provide access for a forklift and/or overhead rigging to facilitate installation and/or removal of the HVAC unit **12**. In some embodiments, the rails **26** may fit into "curbs" on the roof to enable the HVAC unit **12** to provide air to the ductwork **14** from the bottom of the HVAC unit **12** while blocking elements such as rain from leaking into the building **10**.

The HVAC unit **12** includes heat exchangers **28** and **30** in fluid communication with one or more refrigeration circuits. Tubes within the heat exchangers **28** and **30** may circulate refrigerant, such as R-410A, through the heat exchangers **28** and **30**. The tubes may be of various types, such as multichannel tubes, conventional copper or aluminum tubing, and so forth. Together, the heat exchangers **28** and **30** may implement a thermal cycle in which the refrigerant undergoes phase changes and/or temperature changes as it flows through the heat exchangers **28** and **30** to produce heated and/or cooled air. For example, the heat exchanger **28** may function as a condenser where heat is released from the refrigerant to ambient air, and the heat exchanger **30** may function as an evaporator where the refrigerant absorbs heat to cool an air stream. In other embodiments, the HVAC unit **12** may operate in a heat pump mode where the roles of the heat exchangers **28** and **30** may be reversed. That is, the heat exchanger **28** may function as an evaporator and the heat exchanger **30** may function as a condenser. In further embodiments, the HVAC unit **12** may include a furnace for heating the air stream that is supplied to the building **10**. While the illustrated embodiment of FIG. **2** shows the HVAC unit **12** having two of the heat exchangers **28** and **30**, in other embodiments, the HVAC unit **12** may include one heat exchanger or more than two heat exchangers.

The heat exchanger **30** is located within a compartment **31** that separates the heat exchanger **30** from the heat exchanger **28**. Fans **32** draw air from the environment through the heat exchanger **28**. Air may be heated and/or cooled as the air flows through the heat exchanger **28** before being released back to the environment surrounding the rooftop unit **12**. A blower assembly **34**, powered by a motor **36**, draws air through the heat exchanger **30** to heat or cool the air. The heated or cooled air may be directed to the building **10** by the ductwork **14**, which may be connected to the HVAC unit **12**. Before flowing through the heat exchanger **30**, the conditioned air flows through one or more filters **38** that may remove particulates and contaminants from the air. In certain embodiments, the filters **38** may be disposed on the air intake side of the heat exchanger **30** to prevent contaminants from contacting the heat exchanger **30**.

The HVAC unit **12** also may include other equipment for implementing the thermal cycle. Compressors **42** increase the pressure and temperature of the refrigerant before the refrigerant enters the heat exchanger **28**. The compressors **42** may be any suitable type of compressors, such as scroll compressors, rotary compressors, screw compressors, or reciprocating compressors. In some embodiments, the compressors **42** may include a pair of hermetic direct drive compressors arranged in a dual stage configuration **44**. However, in other embodiments, any number of the compressors **42** may be provided to achieve various stages of heating and/or cooling. As may be appreciated, additional equipment and devices may be included in the HVAC unit **12**, such as a solid-core filter drier, a drain pan, a disconnect switch, an economizer, pressure switches, phase monitors, and humidity sensors, among other things.

The HVAC unit **12** may receive power through a terminal block **46**. For example, a high voltage power source may be connected to the terminal block **46** to power the equipment. The operation of the HVAC unit **12** may be governed or regulated by a control board **48**. The control board **48** may include control circuitry connected to a thermostat, sensors, and alarms. One or more of these components may be referred to herein separately or collectively as the control device **16**. The control circuitry may be configured to control operation of the equipment, provide alarms, and monitor safety switches. Wiring **49** may connect the control board **48** and the terminal block **46** to the equipment of the HVAC unit **12**.

FIG. **3** illustrates a residential heating and cooling system **50**, also in accordance with present techniques. The residential heating and cooling system **50** may provide heated and cooled air to a residential structure, as well as provide outside air for ventilation and provide improved indoor air quality (IAQ) through devices such as ultraviolet lights and air filters. In the illustrated embodiment, the residential heating and cooling system **50** is a split HVAC system. In general, a residence **52** conditioned by a split HVAC system may include refrigerant conduits **54** that operatively couple the indoor unit **56** to the outdoor unit **58**. The indoor unit **56** may be positioned in a utility room, an attic, a basement, and so forth. The outdoor unit **58** is typically situated adjacent to a side of residence **52** and is covered by a shroud to protect the system components and to prevent leaves and other debris or contaminants from entering the unit. The refrigerant conduits **54** transfer refrigerant between the indoor unit **56** and the outdoor unit **58**, typically transferring primarily liquid refrigerant in one direction and primarily vaporized refrigerant in an opposite direction.

When the system shown in FIG. **3** is operating as an air conditioner, a heat exchanger **60** in the outdoor unit **58** serves as a condenser for re-condensing vaporized refrigerant flowing from the indoor unit **56** to the outdoor unit **58** via one of the refrigerant conduits **54**. In these applications, a heat exchanger **62** of the indoor unit functions as an evaporator. Specifically, the heat exchanger **62** receives liquid refrigerant, which may be expanded by an expansion device, and evaporates the refrigerant before returning it to the outdoor unit **58**.

The outdoor unit **58** draws environmental air through the heat exchanger **60** using a fan **64** and expels the air above the outdoor unit **58**. When operating as an air conditioner, the air is heated by the heat exchanger **60** within the outdoor unit **58** and exits the unit at a temperature higher than it entered. The indoor unit **56** includes a blower or fan **66** that directs air through or across the indoor heat exchanger **62**, where the air is cooled when the system is operating in air conditioning mode. Thereafter, the air is passed through ductwork **68** that directs the air to the residence **52**. The overall system operates to maintain a desired temperature as set by a system controller. When the temperature sensed inside the residence **52** is higher than the set point on the thermostat, or the set point plus a small amount, the residential heating and cooling system **50** may become operative to refrigerate additional air for circulation through the residence **52**. When the temperature reaches the set point, or the set point minus a small amount, the residential heating and cooling system **50** may stop the refrigeration cycle temporarily.

The residential heating and cooling system **50** may also operate as a heat pump. When operating as a heat pump, the roles of heat exchangers **60** and **62** are reversed. That is, the heat exchanger **60** of the outdoor unit **58** will serve as an evaporator to evaporate refrigerant and thereby cool air entering the outdoor unit **58** as the air passes over outdoor the heat exchanger **60**. The indoor heat exchanger **62** will receive a stream of air blown over it and will heat the air by condensing the refrigerant.

In some embodiments, the indoor unit **56** may include a furnace system **70**. For example, the indoor unit **56** may include the furnace system **70** when the residential heating and cooling system **50** is not configured to operate as a heat pump. The furnace system **70** may include a burner assembly and heat exchanger, among other components, inside the indoor unit **56**. Fuel is provided to the burner assembly of the furnace **70** where it is mixed with air and combusted to form combustion products. The combustion products may pass through tubes or piping in a heat exchanger, separate from heat exchanger **62**, such that air directed by the blower **66** passes over the tubes or pipes and extracts heat from the combustion products. The heated air may then be routed from the furnace system **70** to the ductwork **68** for heating the residence **52**.

FIG. **4** is an embodiment of a vapor compression system **72** that can be used in any of the systems described above. The vapor compression system **72** may circulate a refrigerant through a circuit starting with a compressor **74**. The circuit may also include a condenser **76**, an expansion valve(s) or device(s) **78**, and an evaporator **80**. The vapor compression system **72** may further include a control panel **82** that has an analog to digital (A/D) converter **84**, a microprocessor **86**, a non-volatile memory **88**, and/or an interface board **90**. The control panel **82** and its components may function to regulate operation of the vapor compression system **72** based on feedback from an operator, from sensors of the vapor compression system **72** that detect operating conditions, and so forth.

In some embodiments, the vapor compression system **72** may use one or more of a variable speed drive (VSDs) **92**, a motor **94**, the compressor **74**, the condenser **76**, the expansion valve or device **78**, and/or the evaporator **80**. The motor **94** may drive the compressor **74** and may be powered by the variable speed drive (VSD) **92**. The VSD **92** receives alternating current (AC) power having a particular fixed line voltage and fixed line frequency from an AC power source, and provides power having a variable voltage and frequency to the motor **94**. In other embodiments, the motor **94** may be powered directly from an AC or direct current (DC) power source. The motor **94** may include any type of electric motor that can be powered by a VSD or directly from an AC or DC power source, such as a switched reluctance motor, an induction motor, an electronically commutated permanent magnet motor, or another suitable motor.

The compressor **74** compresses a refrigerant vapor and delivers the vapor to the condenser **76** through a discharge passage. In some embodiments, the compressor **74** may be a centrifugal compressor. The refrigerant vapor delivered by the compressor **74** to the condenser **76** may transfer heat to a fluid passing across the condenser **76**, such as ambient or environmental air **96**. The refrigerant vapor may condense to a refrigerant liquid in the condenser **76** as a result of thermal heat transfer with the environmental air **96**. The liquid refrigerant from the condenser **76** may flow through the expansion device **78** to the evaporator **80**.

The liquid refrigerant delivered to the evaporator **80** may absorb heat from another air stream, such as a supply air stream **98** provided to the building **10** or the residence **52**. For example, the supply air stream **98** may include ambient or environmental air, return air from a building, or a combination of the two. The liquid refrigerant in the evaporator **80** may undergo a phase change from the liquid refrigerant to a refrigerant vapor. In this manner, the evaporator **38** may reduce the temperature of the supply air stream **98** via thermal heat transfer with the refrigerant. Thereafter, the vapor refrigerant exits the evaporator **80** and returns to the compressor **74** by a suction line to complete the cycle.

In some embodiments, the vapor compression system **72** may further include a reheat coil in addition to the evaporator **80**. For example, the reheat coil may be positioned downstream of the evaporator relative to the supply air stream **98** and may reheat the supply air stream **98** when the supply air stream **98** is overcooled to remove humidity from the supply air stream **98** before the supply air stream **98** is directed to the building **10** or the residence **52**.

It should be appreciated that any of the features described herein may be incorporated with the HVAC unit **12**, the residential heating and cooling system **50**, or other HVAC systems. Additionally, while the features disclosed herein are described in the context of embodiments that directly heat and cool a supply air stream provided to a building or other load, embodiments of the present disclosure may be applicable to other HVAC systems as well. For example, the features described herein may be applied to mechanical cooling systems, free cooling systems, chiller systems, or other heat pump or refrigeration applications.

As discussed below, a heating, ventilation, and air conditioning (HVAC) system **100**, such as the HVAC unit **12**, the heating and cooling system **50**, and/or the vapor compression system **72**, may include an adaptive air distribution system configured to administer conditioned air according to a distribution of heat within a room, building, or conditioned space. For example, the HVAC system **100** may detect heat sources, such as people, machines, animals, solar loads, and so forth, and may administer conditioned air accordingly to condition the air within the room, building, or conditioned space. In one embodiment, conditioned air may be provided to portions or limited areas of the room, building, or conditioned space to reduce air stratification, such as an uneven distribution of temperatures, within the room, building, or conditioned space. In certain instances, stratified zones may occur if portions of the room, building, or conditioned space contain large, or numerous, heat sources, while other portions of the room, building, or conditioned space contain moderate, or few, heat sources. Particularly, the HVAC system **100** may reduce air stratification by providing individualized heating, ventilation, and/or air conditioning to portions of the room, building, or conditioned space based on the detected heat sources. That is, the HVAC system **100** may provide conditioning air flows in response to a presence of heat sources in addition to, or alternatively to, providing conditioning air flows in response to a changing temperature of the room, building, or conditioned space.

To illustrate, FIG. **5** is a schematic view of the HVAC system **100** that is configured to provide individualized heating, ventilation, and/or air conditioning to a conditioned space, such as to portions of rooms **102**, of a building **104**. While the discussion below focuses on an embodiment of the HVAC system **100** providing conditioned air to portions of the rooms **102**, the techniques described herein may be used to provide conditioned air to portions of a building, such as different rooms, or portions of any other conditioned space.

In the illustrated embodiment, the HVAC system **100** includes an HVAC unit **106**, such as the HVAC unit **12** or the heating and cooling system **50**, heat sensors or thermal light detectors **108**, and an air duct system **110**, which is configured to administer air through outlets **112**, such as variable air volume (VAV) diffusers. Each outlet **112** and/or groups of the outlets **112** may utilize an air control device **113**, such as a variable air volume (VAV) box, which may control a volumetric flow rate of air as it passes through the outlet **112** and/or a reheat terminal, which may control a temperature of air as it passes through the outlet **112**. Similarly, in certain embodiments, the air control device **113** may include fan coils and/or chilled beams. Indeed, in certain embodiments, the HVAC system **100** may be a VAV system, which is configured to adjust a flow rate of the air and/or may be a constant air volume (CAV) system, which is configured to adjust a temperature of the air.

Further, the HVAC system **100** may be communicatively coupled to a controller **114**. The controller **114** may employ a processor **116**, which may represent one or more processors, such as an application-specific processor. The controller **114** may also include a memory device **118** for storing instructions executable by the processor **116** to perform the methods and control actions described herein for the HVAC system **100**. The processor **116** may include one or more processing devices, and the memory **118** may include one or more tangible, non-transitory, machine-readable media. By way of example, such machine-readable media can include RAM, ROM, EPROM, EEPROM, CD-ROM, or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by the processor **116** or by any general purpose or special purpose computer or other machine with a processor. In certain embodiments, the controller **114** may be directly coupled to, or disposed within, the HVAC unit **106**.

The controller **114** may be communicatively coupled to the HVAC unit **106**, the heat sensors or thermal light detectors **108**, and/or the air control devices **113** through a communication system **120**. In some embodiments, the communication system **120** may communicate through a wireless network, such as wireless local area networks [WLAN], wireless wide area networks [WWAN], near field communication [NFC], or Bluetooth. In some embodiments, the communication system **120** may communicate through a wired network such as local area networks [LAN], or wide area networks [WAN].

As discussed herein, the heat sensors or thermal light detectors **108** are configured to detect, measure, and/or determine the presence and the intensity, or concentration, of heat sources of an area. As used herein, the term "thermal light detector" includes thermographic cameras, infrared (IR) sensors, or any other suitable sensor configured to detect IR radiation, or electromagnetic wavelengths within the infrared spectrum, which may indicate that heat is radiating from an object. That is, the heat sensors thermal light detectors **108** may determine an intensity or level of heat of a surface of an object relative to surroundings of the object. In some embodiments, the heat sensors thermal light detectors **108** may be coupled to a ceiling **122** and/or a wall **124** of the room **102**. In some embodiments, the heat sensors thermal light detectors **108** may be associated with a field of view **126**, which may refer to an area of coverage, and with a range **128**, which may refer to a distance from the heat sensor thermal light detector **108** in which the heat sensor thermal light detector **108** may accurately and/or reliably sense IR radiation. Indeed, the field of view **126** and the range **128** may depend at least in part on the type of heat sensor thermal light detector **108** utilized.

The heat sensors **108** may be positioned such that the fields of view **126** of the heat sensors **108** substantially covers an area of a floor **130** of the room **102**. Further, the heat sensors **108** may be positioned such that the range **128** reaches a suitable level within the room. For example, in certain embodiments, the heat sensors **108** may be disposed such that the associated ranges **128** extend approximately to the floor **130**, to approximately a standard body height from the floor **130**, or any other suitable distance from the floor **130**. Overall, the number of heat sensors **108** and their location within the room **102** may depend at least in part on the field of view **126**, the range **128**, and/or other specifications of the heat sensor **108**. In certain embodiments, the heat sensors **108** may be configured to detect a temperature distribution throughout the room **102**.

In certain embodiments, the HVAC system **100** may include one or more thermostats **131**, or temperature and humidity sensors, configured to detect a temperature and/or humidity of the room. The HVAC system **100** may utilize data gathered by the thermostat **131** to calibrate the heat sensors **108** to accurately measure the temperature distribution throughout the room. For example, the thermostat **131** may detect the temperature in a portion of the room **102** in which the thermostat **131** is located, and the heat sensors **108** may detect the concentration of heat in the portion of the room **102** in which the thermostat **131** is located. The controller **114** may utilize the temperature data from the thermostat **131** and heat distribution data from the heat sensors **108** to determine the temperature distribution throughout the room **102**.

As shown in FIG. **5**, certain activities, objects, orientation, and other elements of the room **102** may affect a distribution of heat within the room **102**. To help illustrate, an intensity/level of heat within the room **102** is represented with horizontal lines **138**. For example, the amount of lines **138** vertically stacked in a certain area may be directly related to an amount of heat being distributed within the certain area. As shown, the amount of heat may be increased by the presence of humans **140**, or other organisms, machines **142**, a solar load **144**, and/or other sources of heat. For example, the machines **142** that are in operation, which are illustrated as the machines **142** that are being operated by the humans **140**, may output more heat than the machines **142** that are not in operation, which are illustrated as the machines **140** that do not have the humans **140** adjacent to the machines **142**. Indeed, the machines **142** may be any machine **142** that may output heat, such as computers, televisions, servers, automation equipment, artificial light sources, manufacturing equipment, and so forth. Further, a portion of the room **102** may increase in heat due to the solar load **144**, which may be a result of the proximity of the portion of the room **102** to a window **148** through which solar energy may travel. Therefore, an area of the room **102** adjacent to the window **148**, which is experiencing the solar load **144**, is illustrated with an increased amount of lines **138** to indicate a high intensity heat source in the area. Indeed, as shown, heat sources may be unevenly distributed throughout the room **102**, and the HVAC system **100** may distribute conditioning air flows to the room **102** accordingly.

The HVAC system **100** may detect the distribution of heat, heat sources, a temperature/thermal gradient, or any combination thereof throughout the room **102** via the heat sensors **108**. Particularly, the heat sensors **108** may gather data indicative of the heat distribution, such as a thermal or temperature gradient, throughout the room and communicate the data to the controller **114**. The controller **114** may analyze the data and send corresponding signals to the HVAC unit **106** and/or the air control devices **113** to cool or heat certain portions of the room **102**, such that the temperature distribution throughout the room **102** is substantially constant and substantially matches a set-point temperature. For example, in portions of the room **102** that are determined, via the heat sensors **108** and the controller **114**, to contain higher intensity heat sources may receive cooler air and/or an increased cool air flow with respect to portions of the room **102** that are determined to contain lower intensity heat sources. Similar principals may be utilized by the HVAC system **100** when particularly low intensity heat sources are present that may cause portions of the room **102** to have particularly low temperatures. For example, in portions of the room **102** that are determined, via the heat sensors **108** and the controller **102**, to contain low intensity heat sources may receive warmer air and/or an increased warm air flow with respect to portions of the room **102** that are determined to contain higher intensity heat sources. In certain embodiments, the heat sensors **108** may detect an occupancy distribution of the room **102** and may provide the conditioning air flows accordingly by preemptively cooling areas within higher concentrations of occupancy.

FIG. **6** is a schematic top view of the room **102** showing an embodiment of a distribution of the heat sensors **108** and the outlets **112** throughout the room **102**. In some embodiments, the room **102** may be a large room with a variety of functions such as a ballroom, a cafeteria, a library, a lobby, an office space, a training room, a restaurant, a server room, a call center, or any other suitable type of room. In the current embodiment, the heat sensors **108** are positioned between the outlets **112** such that there are four heat sensors **108** and nine outlets **112**. Indeed, in certain embodiments, the room **102** may include an array of the heat sensors **108**. However, as mentioned above, it is to be understood that the room **102** may include any suitable number of heat sensors **108**. In certain embodiments, the amount of heat sensors **108** may depend on the specifications of the heat sensors **108**, such as the field of view **126**, the range **128**, the resolution, and so forth. For example, in some embodiments, the HVAC system **100** may utilize a single heat sensor **108** with a large field of view **126** configured to substantially cover the room **102**. In some embodiments, the fields of view **126** of the heat sensors **108** may overlap, which may provide for redundancy and/or validation in determining the distribution of heat within the room **102**. In some embodiments, the HVAC system **100** may include one heat sensor **108** per outlet **112** or air control device **113**. In some embodiments, the number of heat sensors **108** and/or coverage of the heat sensors **108** utilized by the HVAC system **100** may be such that only portions of the room **102** are monitored by the heat sensors **108**, such as portions of the room **102** that are expected to have a high variance, or high fluctuation, in heat sources and/or temperatures.

As mentioned above, the heat sensors **108** may gather data indicative of the distribution of heat sources in the room **102** and communicate the data to the controller **114**. In certain embodiments, the heat sensors **108** and the controller **114** may generate a heat map **150**, or two-dimensional (2D) image, of the distribution of heat sources, distribution of temperature, distribution of occupancy, or any combination thereof of the room **102**. The heat map **150** may be displayed on a user interface **152**, such as a graphical user interface (GUI) communicatively coupled to the controller **114**. For example, as shown, due at least in part to the solar load **144** in the room **102** adjacent to the window **148**, the heat map **152** may indicate increased heat in the portion of the room **102** adjacent to the window **148** that is experiencing the solar load **144**. Accordingly, the controller **114** may increase cooling administered through the outlets **112** within the portion of the room **102** experiencing the solar load **144** by actuating the respective air control devices **113**. Indeed, the controller **114** may also increase cooling administered through outlets **112** that are adjacent to other sources of heat, such as machines **142**, humans **140**, and so forth.

As discussed herein, the HVAC system **100** may identify heat sources within the room **102** or other conditioned space and administer an appropriate amount of air at an appropriate temperature to reduce air stratification, such as an uneven distribution of temperatures, within the room **102**, building, or conditioned space. Specifically, the HVAC system **100** may utilize predictive control to preemptively cool or heat portions of the room **102** or building that have been identified as potential causes or areas of air stratification, such as portions of the room **102** having low intensity heat sources, such as cold objects, or high intensity heat sources, such as hot objects. That is, the HVAC system **100** may administer the appropriate or desired amount and temperature of air to the portions of the room **102** or conditioned space having potential sources of air stratification as the potential sources of air stratification enter, or appear within, the portion of the room **102**, or shortly thereafter. In other words, the HVAC system **100** may administer air to condition the room **102** before the potential sources of air stratification are able to cause a significant and/or a noticeable amount of air stratification within the room **102**. Indeed, alternatively or in addition to the HVAC system **100** providing conditioned air based on changes in temperature in the room **102**, the HVAC system **100** may provide condition air based on the presence of sources that could potentially cause changes in temperature. Therefore, because the HVAC system **100** may preemptively cool a space within the room **102**, the HVAC system **100** may operate for a shorter period of time and in more specified areas to condition the room **102**, thereby providing cost efficiency and energy efficiency. Particularly, the HVAC system **100** may provide for cost and energy efficiency relative to systems that provide conditioned air based only on a disparity between a measured temperature of a space and a set-point temperature of the space.

In some embodiments, the amount and temperature of air that the HVAC system **100** supplies to the room **102** may be calibrated according to an intensity and duration of the heat source. That is, if a high-intensity heat source appears in a certain portion of the room **102** for a short amount of time, the HVAC system **100** may supply cooled air to the certain portion of the room **102** for a short amount of time. Similarly, if a high-intensity heat source appears in a certain portion of the room **102** and remains in the certain portion of the room **102**, the HVAC system **100** may continuously supply cooled air to the certain portion of the room **102** at least while the high-intensity heat source remains in the certain portion of the room **102**. In certain embodiments, the HVAC system **100** may detect a rate of temperature change, or rate of change of heat intensity in the room **102**, and may accordingly increase or decrease an amount and/or a temperature of supplied air.

In some embodiments, the heat sensors **108** may be capable of detecting motion within the room **102**. Indeed, in such embodiments, the HVAC system **100** may be capable of determining occupancy of the room **102** via the heat sensors **108**. To this end, the heat sensors **108** may be configured to detect a human form, such as via a detected heat signature. In some embodiments, the heat sensors **108** may detect human forms by detecting a motion or change in detected heat distribution. The heat sensors **108** may also be configured to detect other characteristics or attributes of humans, such as face detection, to determine occupancy of the room **102**. In such embodiments, the heat sensors **108** may send data indicative of the human forms or motion to the controller **114**, which in turn may control the HVAC system **100** to condition the room **102** based on the human forms or motion within the room. As discussed herein, the HVAC system **100** system may adjust an amount and/or temperature of the conditioned air flows by adjusting an operation of the HVAC unit **106** and/or by adjusting operation of the air control devices **113**.

FIG. **7** is a flow chart illustrating a control process **170** of the HVAC system **100**. At block **172**, the HVAC system **100** may operate the heat sensors **108** to detect heat sources within a conditioned space, such as the room **102**. Indeed, the heat sensors **108** may detect infrared (IR) radiation emanating from objects within the conditioned space, thereby detecting heat source outliers of the conditioned space. In other embodiments, the heat sensors **108** may be any other suitable type of sensor. In some embodiments, detecting heat sources within the conditioned space may include detecting a temperature distribution, and/or an occupancy distribution of the conditioned space.

At block **174**, the HVAC system **100** may determine a distribution and intensity of heat sources. Indeed, discussed above, determining the distribution and intensity of heat sources within the conditioned space may include detecting a heat distribution, temperature distribution, occupancy distribution, or any combination thereof. Specifically, the HVAC system **100** may utilize the controller **114** to aggregate and analyze data gathered by the heat sensors **108** indicative of heat distribution throughout the room **102** to determine the distribution and intensity of heat sources. Analysis of the data may include generation of a heat map of the conditioned space indicating a distribution and/or intensity of heat throughout portions or all of the conditioned space.

At block **176**, the HVAC system **100** may provide conditioning air flows according to the distribution and/or intensity of heat sources within the conditioned space. For example, when the HVAC system **100** identifies certain portions of the conditioned space to include high-intensity heat sources which could potentially cause a rise in temperature in the certain portions, and thereby causing air stratification throughout the conditioned space, the HVAC system **100** may provide the conditioned air flows to prevent the air stratification. In other words, the HVAC system **100** may provide conditioned air flows in response to an uneven or changing distribution of heat sources within the conditioned space prior to a significant temperature change in the conditioned space. In this manner, because the HVAC system **100** may efficiently condition the conditioned space by providing focused conditioning air flows to the certain portions of the conditioned space to reduce air stratification, the HVAC system **100** may provide for an increase in efficiency.

Accordingly, the present disclosure is directed to providing systems and methods for an adaptive air distribution heating, ventilation, and air conditioning (HVAC) system. The adaptive HVAC system may monitor the presence and distribution of heat sources within a conditioned space, such as a room, and may provide conditioning air flows based on a distribution of the heat sources. In this manner, the adaptive HVAC system may preemptively condition the conditioned space before the heat sources cause a significant change in temperature, or comfort level, in the space in which the heat sources are located. That is, the adaptive HVAC system may provide individualized, or targeted air flows, to respective portions of the conditioned space, thereby preventing air stratification and providing for an increase in efficiency.

While only certain features and embodiments of the present disclosure have been illustrated and described, many modifications and changes may occur to those skilled in the art, such as variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, such as temperatures or pressures, mounting arrangements, use of materials, colors, orientations, and so forth, without materially departing from the novel teachings and advantages of the subject matter recited in the claims. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the present disclosure. Furthermore, in an effort to provide a concise description of the exemplary embodiments, all features of an actual implementation may not have been described, such as those unrelated to the presently contemplated best mode of carrying out the present disclosure, or those unrelated to enabling the claimed embodiments. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation specific decisions may be made. Such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure, without undue experimentation.

The invention claimed is:

1. A heating, ventilation, and/or air conditioning (HVAC) system, comprising:

a sensor system configured to detect heat indications within a plurality of areas of a conditioned room, wherein the sensor system comprises a first thermal light detector configured to detect a first heat indication in a first area of the plurality of areas of the conditioned room and a second thermal light detector configured to detect a second heat indication in a second area of the plurality of areas of the conditioned room;

a controller configured to receive data corresponding to the first heat indication and the second heat indication from the sensor system and, based on the data, control airflow distribution, via an airflow distribution system, through a first airflow path terminating at a first air outlet of the conditioned room, wherein the first air outlet corresponds to the first area, and through a second airflow path terminating at a second air outlet of the conditioned room, wherein the second air outlet corresponds to the second area; and

a user interface communicatively coupled with the controller, wherein the controller is configured to generate, based on the data, a two-dimensional heat map of the conditioned room, the two-dimensional heat map of the conditioned room including an illustration of the plurality of areas of the conditioned room and the heat indications superimposed over the plurality of areas of the conditioned room, and wherein the user interface is configured to display the two-dimensional heat map.

2. The HVAC system of claim **1**, comprising the airflow distribution system, wherein the airflow distribution system includes a plurality of flow control devices, wherein the plurality of flow control devices is configured to be actuated to control airflow volume or airflow temperature to the plurality of areas.

3. The HVAC system of claim **1**, wherein the sensor system is configured to detect human forms.

4. The HVAC system of claim **1**, wherein the sensor system is configured to detect additional heat indications within a plurality of additional areas of the conditioned room that are not used for control.

5. The HVAC system of claim **1**, comprising:

a first temperature control device disposed in the first airflow path; and

a second temperature control device disposed in the second airflow path, wherein the first temperature control device comprises a first chilled beam or a first fan coil configured to a first portion of receive refrigerant, and wherein the second temperature control device comprises a second chilled beam or a second fan coil configured to receive a second portion of refrigerant.

6. The HVAC system of claim **1**, comprising a thermostat configured to detect a temperature within the first area, wherein the controller is configured to:

receive temperature data from the thermostat; and

calibrate the first thermal light detector based at least in part on the temperature data.

7. The HVAC system of claim **6**, comprising an additional thermostat configured to detect an additional temperature within the second area, wherein the controller is configured to:

receive additional temperature data from the additional thermostat;

calibrate the second thermal light detector based at least in part on the temperature data; and

determine, based on the first heat indication, based on the second heat indication, and after calibrating the first thermal light detector based at least in part on the temperature data and the second thermal light detector based at least in part on the additional temperature data, a distribution of heat through the plurality of areas of the conditioned room.

8. A heating, ventilation, and/or air conditioning (HVAC) system, comprising:

a sensor system configured to detect a distribution of heat within a conditioned room, wherein the sensor system includes a first thermal light detector configured to detect a first portion of the distribution of heat corresponding to a first area of the conditioned room and a second thermal light detector configured to detect a second portion of the distribution of heat corresponding to a second area of the conditioned room;

a plurality of air control devices configured to be actuated to control airflows to the conditioned room, wherein the plurality of air control devices comprises a first chilled beam corresponding to the first area of the conditioned room and a second chilled beam corresponding to the second area of the conditioned room;

a plurality of physically separate flow paths, wherein each physically separate flow path of the plurality of physically separate flow paths terminates at a corresponding physically separate air outlet of a plurality of physically separate air outlets, wherein the plurality of physically separate flow paths includes a first physically separate flow path corresponding to the first area of the conditioned room and having at least a portion of the first chilled beam extending therein, and wherein the plurality of physically separate flow paths includes a second physically separate flow path corresponding to the second area of the conditioned room and having at least an additional portion of the second chilled beam extending therein; and

a controller configured to receive first data indicative of the first portion of the distribution of heat from the first thermal light detector and second data indicative of the second portion of the distribution of heat from the second thermal light detector, to determine a first target airflow property based on the first data, to determine a second target airflow property based on the second data, to control the first chilled beam to facilitate a first airflow having the first target airflow property through the first physically separate flow path and to the first area of the conditioned room, and to control the second chilled beam to facilitate a second airflow having the second target airflow property through the second physically separate flow path and to the second area of the conditioned room.

9. The HVAC system of claim **8**, wherein the plurality of air control devices comprises a variable air volume (VAV) box or a reheat terminal.

10. The HVAC system of claim **8**, wherein the sensor system comprises an infrared (IR) sensor.

11. The HVAC system of claim **8**, wherein the controller is configured to control each air control device of the plurality of air control devices based on a target temperature distribution throughout the conditioned room being substantially equalized.

12. The HVAC system of claim **8**, further comprising a communication system, wherein the sensor system, the plurality of air control devices, and the controller are communicatively coupled via the communication system.

13. The HVAC system of claim **8**, comprising a user interface communicatively coupled with the controller, wherein the controller is configured to generate, based on the first data, the second data, or both, a two-dimensional heat map of the conditioned room, wherein the two-dimensional heat map of the conditioned room includes an illustration of the first area of the conditioned room, the second area of the conditioned room, and heat indications superimposed over the first area, the second area, or both, and wherein the user interface is configured to display the two-dimensional heat map of the conditioned room.

14. The HVAC system of claim **8**, wherein the first airflow property comprises a first temperature and the second airflow property comprises a second temperature.

15. A heating, ventilation, and/or air conditioning (HVAC) system, comprising:

a first infrared (IR) sensor configured to detect first heat sources within a first area of a room;

a second IR sensor configured to detect second heat sources within a second area of the room;

a controller configured to receive, from the first IR sensor and the second IR sensor, data indicative of the first heat sources and the second heat sources, respectively, and to determine, based on the data, a first desired temperature of a first airflow directed to the first area of the room and a second desired temperature of a second airflow directed to the second area of the room, wherein the first desired temperature is different than the second desired temperature and the first area of the room is different than the second area of the room;

a plurality of fan coils including a first fan coil configured to receive a first portion of refrigerant and to be controlled by the controller to cause the first airflow to have the first desired temperature and a second fan coil configured to receive a second portion of refrigerant and to be controlled by the controller to cause the second airflow to have the second desired temperature, wherein the first fan coil is fluidly separate from the second fan coil; and

a plurality of air outlets including a first air outlet associated with the first fan coil and the first area of the room and a second air outlet associated with the second fan coil and the second area of the room, wherein the HVAC system is configured to deliver, via control of at least the first fan coil and the second fan coil by the controller, the first airflow at the first desired temperature to the first area of the room via the first air outlet and the second airflow at the second desired temperature to the second area of the room via the second air outlet.

16. The HVAC system of claim **1**, wherein the first IR sensor comprises an array of IR detectors.

17. The HVAC system of claim **15**, wherein the HVAC system is configured to determine, based on the data, a distribution of occupancy of the room, and wherein the HVAC system is configured to deliver the conditioned air through each air outlet of the plurality of air outlets according to the distribution of occupancy.

18. The HVAC system of claim **15**, comprising an HVAC unit fluidly coupled to the plurality of air outlets, wherein the HVAC unit is configured to adjust an amount of conditioned air delivered to the plurality of air outlets based on a distribution of heat sources within the room.

19. The HVAC system of claim **15**, comprising a user interface communicatively coupled with the controller, wherein the controller is configured to generate, based on the data, a two-dimensional heat map of the room, wherein the two-dimensional heat map of the room includes an illustration of the first area of the room, the second area of the room, and heat indications superimposed over the first area, the second area, or both, and wherein the user interface is configured to display the two-dimensional heat map of the room.

20. The HVAC system of claim **15**, wherein the controller is configured to cause the first airflow at the first desired temperature to be delivered to the first area of the room through the first air outlet at a point in time, and wherein the controller is configured to cause the second airflow at the second desired temperature to be delivered to the second area of the room through the second air outlet at the point in time.

21. The HVAC system of claim **15**, comprising a first fan, first diffuser, or first damper corresponding to the first area of the room and a second fan, second diffuser, or second damper corresponding to the second area of the room, wherein the controller is configured to control the first fan, first diffuser, or first damper based on the data to cause a first airflow volume of the first airflow, and wherein the controller is configured to control the second fan, second diffuser, or second damper based on the data to cause a second airflow volume of the second airflow.

22. The HVAC system of claim **15**, wherein the first fan coil is configured to be controlled to cool the first airflow and the second fan coil is configured to be controlled to cool the second airflow.

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